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WEST AFRICAN MONSOON DYNAMICS / EVIDENCE OF CONVECTIVELY COUPLED KELVIN WAVES

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1. Introduction

Climatologies of propagating anomalies of convection in the equatorial region (WK99, WKW00, Roundy and Frank, 2004) show that equatorial Rossby and Kelvin waves, along with the MJO, contribute to a substantial amount of the tropical convection variance. These results suggest that, during the northern spring, up to 20% of the local variance near the equator and the Atlantic Inter-Tropical Convergence Zone (ITCZ) can be ascribed to Kelvin wave activity. Straub and Kiladis (2003, hereafter SK03) show that Kelvin waves are primary modulators of convective activity within the Pacific ITCZ, and that their structures resemble that of theoretical Kelvin waves. Here, we demonstrate evidence of Kelvin wave modulating convection over both West and Central Africa at a level at least as large as easterly waves do, and being present also out of the northern summer.

2. Detection of convectively coupled Kelvin waves

A spatial EOF (SEOF) analysis has been performed on Kelvin filtered OLR values over the domain (10°S–30°N/30°W–30°E) for June-September 1979-2000. To determine the number of Principal Components (PC) to be retained, the Scree test and the North rule of thumb were used after taking into account the effect of the autocorrelation on the number of independent data. Following these constraints, PC1/PC2 form an "effectively degenerate multiplet" well separated from PC3. PC1 and PC2 represent respectively 16.3% and 15.3% of the filtered total variance and as a pair represent eastward propagating Kelvin waves. Here, focus is given to the combination of EOF1 and EOF2 ("EOF12") of the dominant mode that explains more than 30% of the filtered total variance.

In the following, we will call wet (dry) Kelvin phase when a Kelvin wave occurrence over West and Central Africa is associated with negative (positive) OLR anomalies, that is higher (weaker) convective activity in the ITCZ. Figure 1 shows the wet minus dry composite sequence associated to EOF12 reconstructed ITCZ index (10°W-10°E/7.5°N-12.5°N), for the non-filtered OLR (shaded), the non-filtered 925hPa wind (vectors) and 925hPa geopotential fields. The OLR data are from the NOAA (National Oceanic and Atmospheric Administration) (see Liebmann and Smith, 1996) and are used as a proxy for deep convection; and wind and geopotential comes from the updated version of the NCEP/NCAR reanalysis the NCEP-DOE AMIP-II Reanalysis (R-2) (see Kalnay et al., 1996 and Kanamitsu et al., 2002). High significant non-filtered OLR anomalies confirms that the Kelvin wave signal has a large impact on convection on Africa and the tropical Atlantic. It yields a typical amplitude of the convection modulation of up to 35 W/m^2 (that is about plus or minus 15 W/m^2 around the mean) associated with this wave activity. The OLR anomaly pattern evolves from a zonal orientation over the Atlantic to a northwest-southeast one over West and Central Africa and a meridional oriented one over East Africa before disagregating. As in the upper-troposphere, the near-surface structure is in rough agreement with theoretical equatorially trapped Kelvin wave solution on an equatorial β-plane (Matsuno 1966). As in Kelvin waves over the Pacific (SK03), passage of the wave is preceded by easterly and followed by westerly wind anomalies, in phase with negative and positive geopotential perturbations respectively, the whole structure propagating at the same speed. More precisely, westerly anomaly winds correspond with the negative OLR anomalies while easterly anomalies precede the negative OLR anomalies by about two days. Most of the flow is in the zonal direction as predicted by theory, although the strong monsoonal heating over West Africa does favor meridional southerly inflow. This wind field anomaly pattern leads to an enhancement of moisture inland zonal flow component along the Guinean coast and off the Fouta-Djalon orography at the location of the "westerly low-levels jet" pointed out by Grodsky and Carton (2001). The convergence of westerly and easterly flows contributes then to the enhanced convection over West and Central Africa. Also, as in the Pacific (SK03), there is a tendency for the dynamical fields to be much more symmetric about the equator, with large Southern Hemisphere signals, even though the convection is concentrated well north of the equator, at the latitude of the ITCZ (about 10°N at the full development of the African monsoon). The effect of strong heating over the African continent results however in a perturbation of the classical Kelvin wave structure when compared to the open ocean over the Atlantic, although the OLR signal continues to propagate eastward.

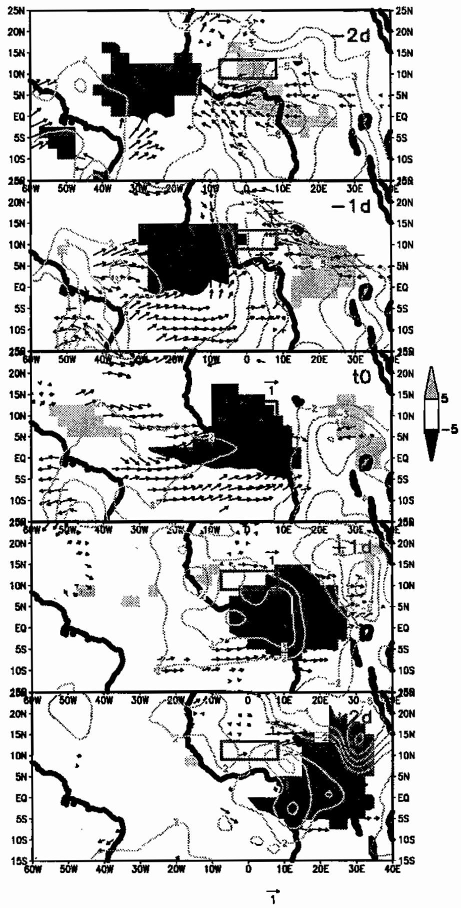

Figure 1 : Composite time sequences based on the OLR Kelvin-filtered ITCZ index (red box) reconstructed by SEOF12. From the standardized ITCZ index time series, we retained the dates (called t0) where this index is maximum (minimum) and greater (lower) than 1.5 to define a dry (wet) Kelvin phase. The respective wet minus dry Kelvin phases composite sequences are shown for non-filtered OLR (shaded), non-filtered 925hPa wind field (vectors) and non-filtered 925hPa geopotential field (contours); shown OLR and wind values are significant at the 95% level. These sequences go (top left to bottom right) from t0-2 days to t0+2 days with a one day lag (day marked on the right corner). OLR anomalies are expressed in W.m^{-2}, geopotential in mgp, and vector scale (m.s^{-1}) is displayed below. The ITCZ box is displayed on each map.

3. Conclusion

Kelvin wave appears to be a synoptic scale weather system factor modulating convection in the ITCZ over tropical Atlantic and West and Central African monsoon at least as strong as African easterly waves.

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Convective wind system with aerosols, named “haboob”, Hombori in Mali, West Africa.